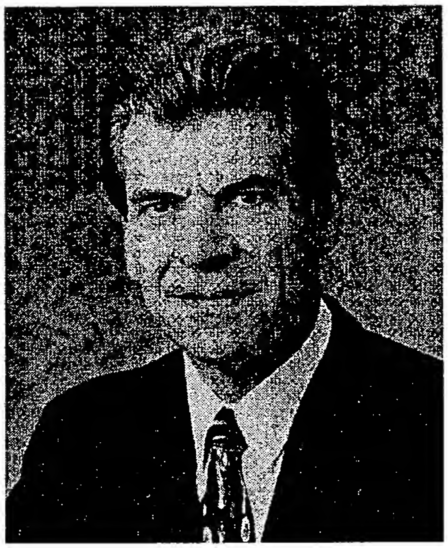
OUTLOOK
Oremet-Wah Chang
An Allegheny Technologies Company
VOL. 20, NO. 4 PRODUCERS AND FABRICATORS OF REFRACTORY AND REACTIVE METALS 4TH QUARTER 1999

Corcoran Named ATI President/CEO



Thomas A. Corcoran

Allegheny Technologies Incorporated recently named Thomas A. Corcoran as President and Chief Executive Officer. Mr. Corcoran succeeds Richard R Simmons, who is currently Chairman of Board of Directors. Mr. Simmons plans to retire from his current position at Allegheny Technologies Annual Meeting in May 2000.

Mr. Corcoran has over 32 years of diversified experience in increasingly responsible operational and senior management positions at large public companies. This experience includes senior-level positions at General Electric, GE Aerospace, Martin Marietta Corporation Electronics Group, and Lockheed Martin.

As President and Chief Operating Officer of Lockheed Martin's electronics sector, Mr. Corcoran was instrumental in growing the business from $3.5 billion to $8 billion in annual revenues. These and other successful efforts led to Mr. Corcoran's appointment as President and Chief Operating Officer of the space and strategic missiles sector of Lockheed Martin Corporation, his most recent position.

Mr. Corcoran holds a bachelor's degree in engineering from Stevens Institute of Technology and has been a featured speaker in numerous business and industry forums as well as a guest lecturer at Worcester Polytechnic Institute, Dartmouth College, and Stanford University.

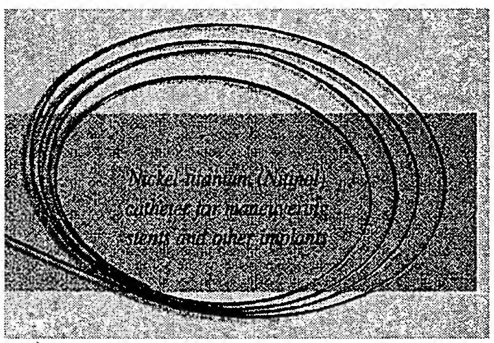
In his new role, Mr. Corcoran will lead specialty materials producers Allegheny Ludlum, Allvac, Oremet-Wah Chang, Titanium Industries, Rome Metals, Metalworking Products, Casting Service, and Portland Forge into the next millennium. For the latest news and detailed product information, refer to the Allegheny Technologies' web site at www.alleghenytechnologies.com.

ATI Changes Name and Focus

Allegheny Technologies Incorporated recently announced its name change from Allegheny Teledyne Incorporated. With the transition, comes the spin-off of Teledyne Technologies and Water Pik Technologies. Allegheny Technologies, of which Oremet-Wah Chang is part, is now focused as one of the largest and most diversified producers of specialty materials in the world. The new corporation consists of the following operating units:

Allegheny Ludlum, a leader in the technology, production and marketing of flat-rolled specialty materials, including stainless steels, silicon electrical steels, tool steels, and other advanced alloys; Allvac, a leader in the technology and production of nickel-based and cobalt-based alloys and superalloys, premium titanium alloys, and specialty steel alloys; Oremet-Wah Chang, a leader in the technology and production of specialty materials, including zirconium, hafnium, niobium, titanium, vanadium, silicon tetrachloride, and zirconium and hafnium chemicals; Titanium Industries, a leading distributor of titanium and zirconium mill products; Rome Metals, a provider of specialized machining and finishing services to titanium, zirconium, nickel alloy, and other metals producers; Metalworking Products, an integrated supplier of tungsten and molybdenum powders, mill products, and tungsten carbide cutting tools; Casting Services, a leading producer of large gray and ductile iron castings; and Portland Forge, a leading producer of precision impression die steel forgings.

For more information on Allegheny Technologies Incorporated and the individual companies listed above, refer to the corporation's web site at www.alleghenytechnologies.com.



Q&A:

The following question and answer was written, with the help of Dr. Yoji Kosaka, of Oremet-Wah Chang. This issue's Q&A column discusses a new titanium alloy that Dr. Kosaka invented for ballistic armor. Dr. Kosaka has over 25 years' experience in advanced materials research and development with NKK Corporation, International Light Metals, and Oremet-Wah Chang. He earned his Doctor of Engineering in Materials Science and Metallurgical Engineering from Tohoku University, Sendai, Japan.

New Armor Alloys

QUESTION:

What new advanced materials are available that provide advantages over conventional armor alloys, such as Ti-6AI-4V or 11-6AI-4V ELI (extra low interstitial)?

ANSWER:

In recent years, Ti-6A1-4V and Ti-6A1-4V ELI alloys have been used to produce armor because they provide better ballistic resistance than steel or aluminum alloys. Lightweight titanium alloys are referred to as being "more mass efficient" with respect to ballistic properties than steel or aluminum alloys; but the ballistic property of alloys like Ti-6A1-4V is not satisfactory. Ti-6A1-4V ELI exhibits a better ballistic property, but is expensive to produce due to low oxygen requirement. As a result, Oremet began the search for new titanium alloys with properties that meet or exceed current military standards and that can be manufactured less expensively than conventional alloys.

The search yielded an answer. On Nov. 9, 1999, OWC was awarded a patent for "titanium alloys, comprising aluminum, vanadium, iron, and a relatively high oxygen content, and products made using such alloys, including ballistic armor."

The U.S. Army Research Laboratory, at Aberdeen Proving Ground, Maryland tested plates produced out of the alloys, using a 20mm fragment-simulating projectile fired from a rifled Mann barrel and varying the striking velocity.

No cracks were observed following ballistic tests on plates made from several of the different alloys tested. The V50 values (velocity of projectile that gives a 50% chance of partial or complete penetration) for the plates made from OWC's new alloys proved to be significantly higher than those reported for the standard Ti-6A1-4V alloy. However, it was also found that armor plates having oxygen contents greater than 0.3% (as was the case with two of the alloys tested) may have reasonably high V50 values, but can develop severe cracks that make them questionable for use in armor applications.

We believe there are many potential uses for the alloys that exhibited superior test results. Our new titanium alloy products can be fashioned to meet the requirements of a variety of applications, including structural devices. As mentioned earlier, these alloys are particularly useful for forming ballistic armor plates. In addition, these alloys are more economical to produce than traditional titanium armor products (due to less stringent oxygen requirements, OWC can use a higher percentage of recycle in the raw material mix), opening the door to new possibilities for OWC's current and future customers.

To discuss new opportunities or for more information on the alloy and its potential applications, contact Program Manager Larry Martin at 541-812-7094 or reach him by fax at 541-812-7098. Yoji Kosaka can be reached by phone at 541-812-7042 or by fax at 541-812-7455.

Corrosion Lab Chronicles: Pickling

By Jack Tosdale, OWC Senior Corrosion Engineer

When working with reactive metals like titanium, not paying attention to details can often get mills, fabricators, and others in a pickle. Today's environmental quality regulations require operators of pickling tanks using nitric acid to reduce the nitrogen oxides that are emitted during the pickling process. Since the pickling of Oremet-Wah Chang's titanium products involves

nitric acid, this is an issue worth studying.

Currently, the pickling bath for our titanium products contains about 30% to 50 % nitric acid and 1% to 7% hydrofluoric acid (HF). We use a 10-to-1 ratio of nitric acid to hydrofluoric acid to prevent the pickup of hydrogen during pickling caused by excess HE

Recently, the Corrosion Laboratory performed an experiment to establish the amount of hydrogen pickup when pickling titanium strip in a bath with a lower-than-normal concentration of nitric acid. The pickling process involves running the Ti strip through a series of baths for 2 to 2.5 minutes (in each bath). The typical process includes:

1. 15 - 20% Sulfuric acid at 80°C - 100°C

2. Water rinse

3. 3.5 - 4.5% Hydrofluoric acid + <1% Nitric acid at 60°C - 85°C

4. Water rinse

To simulate the pickling operation, Corrosion Lab technicians soaked samples of 0.063-in.-thick Ti grade 2 sheet in each solution (in turn) for 2.5 minutes. Technicians performed test at the low and high temperatures for each solution. Acid compositions were 19% sulfuric and 3.8% HF plus 0.5% nitric, by volume.

Lab personnel also performed a side experiment to determine whether the Ti strip would pick up more hydrogen in the sulfuric solution or in the HF and nitric solution. The same acid concentrations as above were used at temperatures of 80°C and 90°C. Samples were soaked for 2.5 minutes at 80°C and for 2.5 and 10 minutes at 90°C to test the extremes of process conditions.

Samples of the raw metal and pickled metal were analyzed for hydrogen content. Because there was no pick-up in hydrogen detected, metallurgical examinations were not performed. The results of the hydrogen analyzes are included in the following table.

As the data shows, there is no difference in the hydrogen levels in any of the test coupons compared to the starting material. In older literature, the recommended solution contained at least 15 times more nitric acid than hydrofluoric acid to prevent the uptake of hydrogen during pickling. At the low temperatures used in this experiment with the extremely low nitric acid content, the uptake of hydrogen was not significant. It appears that the amount of nitric acid in this pickling process can be reduced; however, we highly recommend further testing to duplicate processing conditions.

For more information on this pickling experiment, contact Oremet-Wah Chang's Corrosion Lab at 541-917-6777. (Note: Derrill Holmes performed the testing described in OWC's Corrosion Lab and Lloyd Fenwick documented the findings in an internal report.)

Experiment	Hydrogen (ppm)	Corrosion Rate (mpy)
Experiment 1 *(2.5 minutes in each solution with water rinses)*		
A. Sulfuric bath at 80°C and HF + Nitric bath at 60°C	21	18000
B. Sulfuric bath at 99°C and HF + Nitric bath at 85°C	28	23000
Experiment 2 *(Soak separately in each solution)*		
A. Sulfuric bath at 80°C, 2.5 minutes	24	0
B. Sulfuric bath at 90°C, 2.5 minutes	18	282
C. Sulfuric bath at 90°C, 10 minutes	18	3000
D. HF+Nitric bath at 60°C, 2.5 minutes	29	32000
E. HF+Nitric bath at 90°C, 2.5 minutes	21	57000
F. HF+Nitric bath at 90°C, 10 minutes	18	45500
Starting Material	25	—

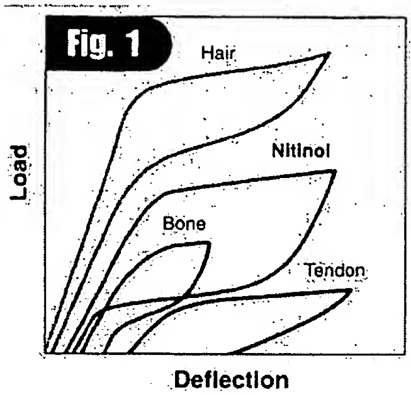
Nitinol- A NiTi Material with Unusual Properties

By Dieter Stockel, *Cordis - Nitinol Devices & Components, Inc., Fremont, CA, USA*

Oremet-Wah Chang is a major supplier of nickel-titanium mill products for medical and other applications. These nickel-titanium (Nitinol) alloys exhibit a combination of properties which make them particularly suitable for the manufacture of self-expanding stents. Some of these properties are not possessed by other materials currently used to manufacture stents. This article describes the fundamental Nitinol properties of shape memory and superelasticity. Material properties and device characteristics such as elastic deployment, thermal deployment, kink resistance, constancy of stress, dynamic interference, biased stiffness, magnetic resonance imaging (MRI) compatibility, radiopacity and biocompatibility, are discussed.

Introduction Nitinol alloys are rapidly becoming the materials of choice for use in self-expanding stents, graft support systems, filters, baskets, and various other devices for interventional procedures. Companies such as Bard-Angiomed (Memotherm), Boston Scientific (Symphony a.o.), Medtronic-AneuRx, Nitinol Medical Technologies, World Medical Technologies, and Cordis offer Nitinol products, the performance of which is based on the highly unusual properties of these Nitinol alloys.

The best-known properties of Nitinol alloys are their superelasticity and thermal shape memory. While the term 'shape memory' describes the phenomenon of restoring a predetermined shape by means of heating, having "plastically" deformed that shape, the term superelasticity refers to the enormous elasticity of these alloys, which can be ten times greater than the best stainless steels used in medicine today. Although both effects are clearly spectacular, they are not the only important properties of the material. In this article, features such as biome-chanical compatibility, constancy of stress, dynamic interference, and "biased stiffness" will be described. In combination with strength, fatigue resistance, biocompatibility, and MRI compatibility, these Nitinol- specific properties allow interesting solutions for the design of superior medical devices [1].



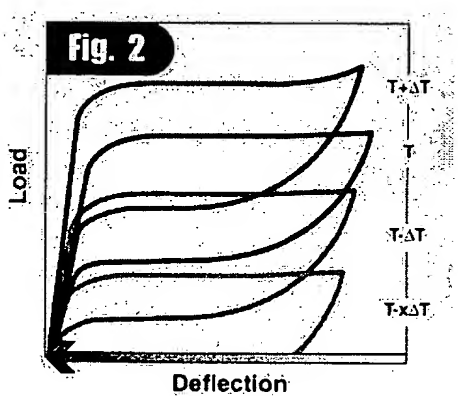
Deformation characteristics of natural materials and Nitinol [2].

Superelasticity and Shape Memory of Nitinol

Conventional metallic materials such as Stainless Steel, Titanium, and Elgilloy a.o., which are used in stents, filters and other interventional devices, exhibit a distinctly different elastic deformation behavior from that of the structural materials of the living body. The elastic deformation of these metals and alloys is limited to = 1% strain and elongation typically increases and decreases linearly (proportionally) with the applied force. In contrast, natural materials, such as hair, tendon, and bone can be elastically deformed, in some cases, up to 10% strain in a non-linear way [2]. When the deforming stress is released, the strain is recovered at lower stresses. As shown in Fig. 1, the loading/unloading cycle is characterized by a pronounced hysteresis.

A similar behavior is found with Nitinol alloys, which are equiatomic or near-equiatomic intermetallic compounds of Titanium and Nickel. Fig. 2 shows a characteristic load/deflection (stress/strain) curve for a Nitinol alloy wire at body temperature (T in Fig. 2; as will be shown later, the properties of Nitinol alloys are strongly temperature dependent). As with natural materials, the loading and unloading curves show plateaus, along which large deflections (strains) can be accumulated on loading, or recovered on unloading, without significant increase or decrease respectively in load (stress). Because a deformation of more than 10% strain can be elastically recovered, this behavior is called "superelasticity", or sometimes more scientifically "pseudoelasticity". It is the basis for most applications of Nitinol in medical devices.

If the temperature is raised, for example, 10°C, the complete hysteresis loop, i.e. loading and unloading curves, it shifts to a higher level (denoted T+TA in Fig. 2). However, the qualitative appearance is maintained. Lowering the temperature by 10° C, however, will shift the hysteresis loop to a lower level (TAT). Lowering the temperature even further will cause the load to reach zero before the deflection is recovered, i.e. the sample will stay deformed at this temperature(T-xΔT). If the temperature is increased to ≥25°C after unloading, the deformation will be recovered thermally. This effect is called thermal shape memory, or simply shape memory.



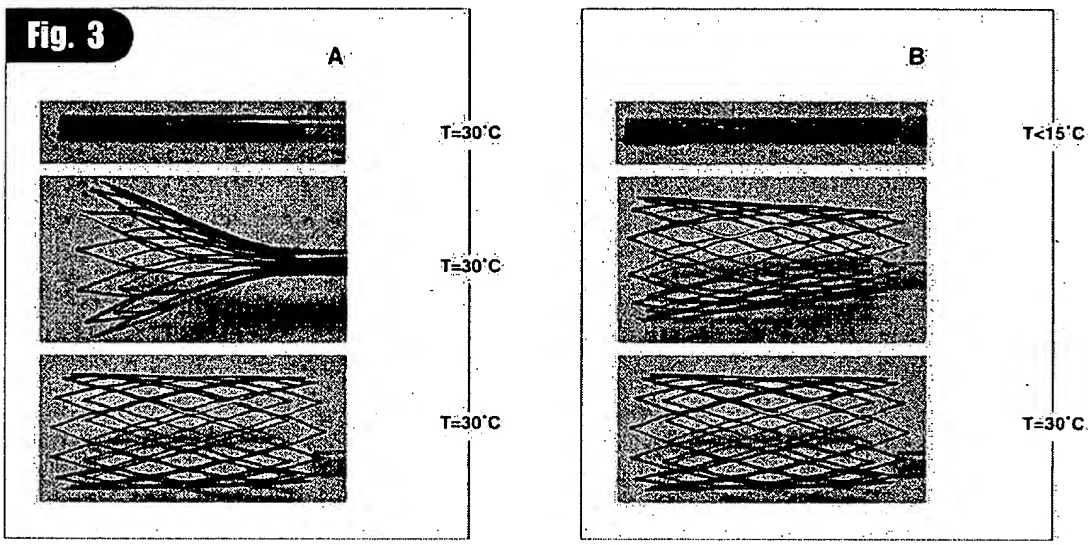
Influence of temperature on the deformation characteristics of Nitinol.

The temperature at which the material can no longer recover the elastic strain, depends on the alloy composition and

processing and can be adjusted to between ~ -20°C and approximately +100°C. This transition temperature is an important characteristic of Nitinol components used in medical applications. Nitinol alloys are superelastic over a temperature range of ~ 50°C above the transition temperature.

At higher temperatures, Nitinol alloys gradually loose their ability to recover the deforming strain until, at a certain maximum temperature (typically 100°C), they behave like a "normal" material. An alloy with a transition temperature of 25°C, all but ~ 0.5% of the deforming strain after being deformed by 8% in the temperature range between 25-75°C. The same alloy can be deformed "plastically" up to 8% (under ideal circumstances) below 25°C and its shape restored by heating to above 25°C *(Note: this description is simplistic. The transition temperature in reality is not a distinct temperature, but a temperature range).*

The mechanism responsible for both superelasticity and shape memory is a solid-state phase transformation, know as the "thermoelastic martensitic transformation". Detailed explanations can be found in Ref. 3. In the following sections some important device characteristics will be discussed, all of which can be attributed to the specific Nitinol properties and used advantageously in manufacture of self-expanding stents and other medical devices.



(A) Elastic deployment of a 'slotted-tube' type Nitinol stent. (B) Cold deployment and thermal recovery of the stent (demonstration device).

Elastic Deployment

The enormous elasticity of Nitinol allows such alloy devices to be introduced into the body through catheters or other delivery systems with a small profile. Once inside the body, the devices can be released from their constraints and unfolded or expanded to a much larger size. Fig. 3A shows the elastic deployment of a stent of 20 mm diameter I.D. cartridge. In order to fully expand at body temperature (37°C), the transition temperature of the alloy should be ≤30°C. If full deployment is required at room temperature (20°C), the transition temperature of the alloy should be ≤15°C. Typical expansion ratios for self expanding Nitinol stents are between 1:2-1:5.

As with stents, filters and occlusion devices (Atrial Septal Defect occlusion, Botalli Duct occlusion) can be deployed superelastically through small sized catheters. Nitinol is also used in retrieval baskets and snares.

Thermal Deployment

A stent with a transition temperature of 30°C can be compressed at ≤20°C. It will stay compressed until the temperature is increased to above >30°C. It will then expand to its pre-set shape. If this stent could be kept cold during introduction into the body, it would not expand.

When positioned at the desired location it would warm up by means of body heat and expand. However, this is difficult to accomplish. All self-expanding stents are constrained in the delivery system to prevent premature deployment. Stents could

theoretically be built with transition temperatures of 40°C. These stents would have to be heated after delivery to the site to make them expand. Fig. 3B shows the stent in Fig. 3A released from a cooled delivery cartridge. The stent stays compressed until its temperature exceeds the transition temperature of 30°C.

The Simon Vena Cava Filter (Nitinol Medical Technologies) was the first shape memory vascular implant to use the property of thermal deployment. The device is preloaded in a catheter in its low-temperature state. Flushing chilled saline solution through the catheter keeps the device in this state while positioning it to the deployment site. Upon release from the catheter the device is warmed by body heat and recovers its "pre-programmed" shape.

Constant Force (Stress)

As shown in Fig. 2, an important feature of superelastic Nitinol alloys is that their unloading curves are flat over a wide deflection (strain) range. This allows the design of devices which apply a constant force or load (stress) over a wide range of shapes. Stents deployed in vessels, therefore, exert an almost constant force independent of the amount of unresolved recovery *(Note: it is typically recommended that stents with diameters 1 to 2 mm larger than the vessel diameter are used).*

The orthodontic archwire was the first product to use this property. Stainless steel and other conventional wires are regularly tightened by the orthodontist. As treatment continues, the teeth move and the force applied by stainless steel wires quickly relaxes according to Hook's law. This causes treatment to slow, retarding tooth movement. In contrast Nitinol wires are able to "move with the teeth", applying a constant force over a very broad range of treatment times and tooth positions.

Dynamic Interference

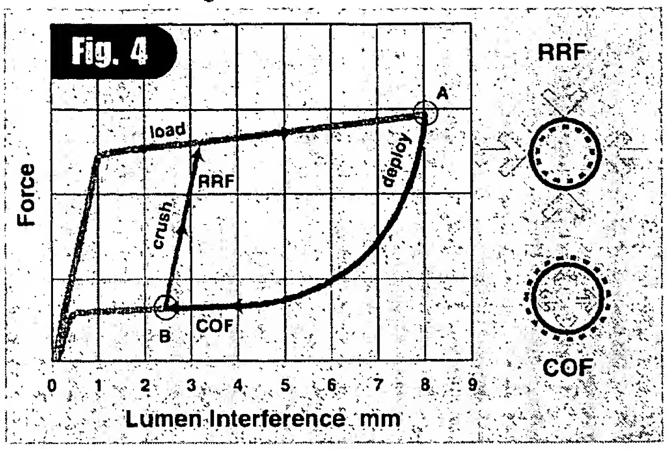
Self-expanding Nitinol stents will always expand to their pre-set diameters with no recoil, while balloon-expandable stents have to be overexpanded to achieve a certain diameter (due to the elastic springback after deflation). The Nitinol stent will continue to gently push outwards against the vessel wall after deployment. Typically, the pre-set diameter of a Nitinol stent is = 1 2 mm greater than the target vessel diameter. Should the vessel increase in diameter, the Nitinol stent will also expand until it reaches its final diameter.

Biased Stiffness (Force Hysteresis)

The most unusual feature of Nitinol alloys is the force or load hysteresis. While in most engineering materials load (or stress, if normalized) increases with deflection (strain) upon loading and decreases along the same path upon unloading, Nitinol exhibits distinctly different behavior. After an initial linear increase in load with deflection, large deflections can be obtained with only a small further load increase. This is called the loading plateau. The end of this plateau is reached at ~ 8% strain. Unloading from the end of the plateau region causes the load to decrease rapidly until a lower plateau (the "unloading plateau") is reached. Deflection is recovered in this region with only a small decrease in load. The last portion of the deforming strain is finally recovered in a linear fashion. The unloading stress **can** be as low as 25% of the loading stress.

Nitinol offers an intriguing array of properties not found in other engineering materials...

The 'biased stiffness' of a stent made from superelastic Nitinol is illustrated in Fig. 4. A stent is compressed into the delivery system following the loading curve to point A. Upon release from the delivery system inside the vessel it expands, following the unloading path of the stress/strain curve. At point B, it reaches the diameter of the vessel lumen, positioning itself against the vessel wall with a low outward force (chronic outward force; COR). As can be seen from the Fig. 4, this force remains nearly constant, even if the vessel increases **in** diameter (dynamic interference). If the vessel contracts, through spasms for instance, or is compressed from the outside, the stent resists deformation with a higher force (radial resistive force: RRF). In such a way, the stress hysteresis of Nitinol allows the design of self-expanding stents with biased stiffness, meaning that the stents exert only small outward force but resist deformation with a much greater force.



Deformation characteristics of natural materials and Nitinol [2].

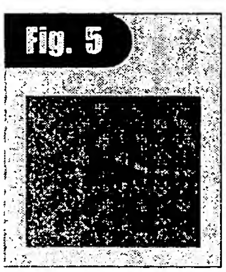
Kink Resistance

Nitinol wires, by virtue of their kink resistance and torquability, have been used in guidewires (see picture at top of page) since the early 1980s. These wires can be bent 10 times more than stainless steel wire without permanent deformation. For example, a 0.035 in. diameter Nitinol wire can be wrapped around a .5 in. diameter mandrel without taking a set, while a stainless steel wire of the same diameter can only be bent around a 5 inch diameter mandrel without being permanently deformed.

Kink resistance is an important feature of Nitinol for stents in superficial vessels that could be deformed by external forces. The carotid artery is a prime example. There is a perceived risk that balloon-expandable stents deployed in carotid arteries can be permanently deformed by external pressure, resulting in a partially or completely blocked vessel, once the buckling strength of the stent is exceeded. Although Nitinol stents typically don't have the buckling strength of stainless steel stents, they cannot be permanently deformed by external forces. Nitinol stents can be completely compressed (crushed) flat and will return to their original diameter when the deforming force is removed.

MRI Compatibility

Nitinol is non-ferromagnetic with a lower magnetic susceptibility than stainless steel. MRI compatibility is directly related to the susceptibility properties of a material relative to human tissue. Therefore, Nitinol produces fewer artifacts than stainless steel and is similar to pure titanium in this regard. Fig. 5 shows an MRI image of a partially deployed Nitinol stent (spin echo sequence, 0.2 T scanner) [4]. Most features of the stent are clearly visible. It has to be noted, however, that processing of the material can significantly influence the quality of the MRI image.



MRI image of a titanium deployed Nitinol stent [4]

Biocompatibility

Nitinol alloys contain a higher portion of Nickel than stainless steels. This causes understandable concern because Nickel is considered to be toxic. However, as Nitinol is an intermetallic compound and not an alloy in the metallurgical sense, the the bonding force of Nickel to Titanium is much stronger than that of

Nickel to the alloy components in stainless steel. Moreover, as Nitinol oxidizes after proper surface treatment, it forms a TiO_2 layer with no Nickel present at the surface [5]. Polarization testing in Hank's solution has repeatedly shown that Nitinol is chemically more stable and less corrosive than stainless steel [6]. In Europe and Asia, Nitinol components have been implanted in humans since the early 1980s, with vascular and non-vascular stents being implanted since the early 1990s. A few years ago, the Simon Vena Cava Filter and Mitek Suture Anchor System, which are both permanent Nitinol implants, were approved by the Food and Drug Administration (FDA) in the US. Recently, the FDA has approved the Nitinol Radius Coronary Stent (Scimed).

Radiopacity

Nitinol produces a fluoroscopic image which is comparable to that of stainless steel, if the mass and dimensions of the parts examined are similar. Although this degree of radiopacity is sufficient in many cases, an improvement would be beneficial. While stainless steel can be gold-coated, for example, with sufficient thickness to enhance radiopacity, layers of gold and other radiopaque materials might negatively influence the superelastic performance of Nitinol.

Conclusions

Nitinol offers an intriguing array of properties, not found in other engineering materials, which are useful for the manufacture of self-expanding stents. The medical device industry has recognized the potential of this material and uses it in a wide range of vascular and non- vascular stents, as well as for other devices and accessories. For more information on Nitinol stents and medical devices, contact NDC at 510-623-6996. For more information on nickel-titanium mill products, call OWC at 541-967-6920.

References

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Henson Appointed as Nickel Titanium Manager

Rob Henson

Oremet-Wah Chang is pleased to announce the appointment of Mr. Rob Henson as Manager, Nickel Titanium Business Development. In his new position, Mr. Henson will help define and develop new applications for OWC's shape-memory and superelastic NiTi alloys as well as service existing customers and markets. His unique background in metallurgy, testing, and market development provides him with all the tools necessary to help turn customers' ideas into saleable products.

Mr. Henson experience includes 12 years in OWC's R&D laboratory. Since he moved to business development in 1993, he

has been instrumental in developing markets for the company's nickel-titanium, titanium-niobium, CP titanium, and Zircadyne Zirconium® product lines. Over this period, he has authored many articles for *Outlook* and the trade press, most recently a Question and Answer column discussing Titanium Grades 7 and 16.

To contact Mr. Henson, phone him at 541-967-6920, reach him by fax at 541-967-6994, or e-mail him at rob.henson@oremetwahchang.com.

Tiadyne 3510™

By Jack Tosdale, *OWC Senior Corrosion Engineer*

Tiadyne 3510 is a titanium based alloy with 35% zirconium and 10% niobium (refer to Table 1) that can have a martensitic structure at room temperature, have high strength, yet be very weldable, formable, and machinable. It can be surface hardened by oxidation for very high wear resistance. This alloy can be cast and has potential applications in prosthetic devices, firing mechanisms in firearms, lightweight springs, and large hand tools, where a lower weight with high strength is desirable. Tiadyne 3510's corrosion resistance is quite similar to that of unalloyed titanium and in some cases is even greater.

The alloy's beta to alpha transus is about 635°C, so it is necessary to heat to 850°C before quenching to form the martensite. Yield and tensile strengths (refer to Table 2) are further increased by aging at 450°C to 550°C. This aged alloy demonstrates a very low modulus of elasticity, 10.4 million psi, and does not display a ductile-to-brittle transition to -50°C. At elevated temperatures, it is superplastic. After the oxidation step, the oxide layer is very hard and adherent, making Tiadyne 3510''' very useful for articulating parts.

The elements making up this alloy are all non-toxic and non-carcinogenic. It is produced by traditional metallurgical processing and requires no special costly treatments. The alloy is available in all mill forms, including plate, sheet, rod, wire, pipe, tubing and bar. Tiadyne 3510 is very amenable to hot or warm forging, particularly closed die forging. Sharp corners, indentations and other details can be accurately produced. This is made possible by its superplasticity at 700°C. This alloy exhibits excellent detail reproduction in investment casting, with no appreciable segregation. Surface quality is very good.

Tiadyne 3510 exhibits excellent characteristics for biomechanical uses such as prosthetic devices and has distinct potential in other areas, such as high impact parts, where weight, strength, and wear resistance are important. (For example: the firing mechanism of firearms.) Also, due to this alloy's low stiffness, it can be used for strong lightweight springs. Another potential use that may seem unusual is large hand tools. Shipwrights, millwrights, and others may welcome large hand tools that are 40% lighter than steel components. The initial cost would be higher, but the hardened surface would create a tool with an infinite life span.

Table 1
Typical Chemical Composition

Element	Weight
Carbon	0.004 - 0.006
Oxygen	0.07 - 0.13
Hydrogen	0.0015 - .003
Nitrogen	0.0015 - .003
Zirconium	35.0 - 35.5
Niobium	10.0 - 11.0
Titanium	Remainder